CADDET energy efficiency IEA OECD

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Underground GSHP system

Unique ground-source heat pump system at real-estate office

Summary

In 1990 a ground-source heat pump (GSHP) system was installed in a new office building in downtown Toronto. To save space in this high-density location, the system was installed directly beneath the building. The system is designed to withstand freezing temperatures and measures were taken to ensure that the temperature of the closed underground loop does not fall below 0°C. These included substituting water in the loop for a propylene ethynol solution and adding a gas-fired boiler. Although this system is more expensive than a conventional one, it results in annual natural gas savings of 96%.

Highlights

- **Natural gas savings of 96%**
- **Major space savings**
- **Annual energy cost savings of CAD 6,600**
- **Uses non-CFC refrigerants**

Trustcan Realty Office, Toronto.

Aim of the Project

The Trustcan Realty Office building, completed in 1990, is a three-storey building located in downtown Toronto. Encouraged by Ontario Hydro, one of the main electricity suppliers in the region, the property owners looked for a new energy-efficient way to air-condition the interior of the building. An energy-saving GSHP system was selected, however due to the severe space restrictions in this high-density location, the system had to fit into the space limitations of the site. The system was therefore installed immediately beneath the complex. The main part of the ground-source heat pump system was installed underneath the building itself, and a small part beneath the parking garage.

In order to be operational all year round, the system had to be specially designed to withstand continental climate conditions (4,059 degree-days on an 18°C basis). This problem was accentuated by the proximity of the ground loop to the surface. Using a propylene ethynol solution and installing a gas-fired boiler solved this problem.

The Principle

The GSHP system consists of a closed-loop design incorporating a series of boreholes separated from each other by the maximum available space (within the boundaries of the building's foundations). The underground closed-loop is directly linked to multiple heat pumps dispersed throughout the building (this is a direct-expansion system and there is no plate heat exchanger separating the ground loop from the internal building loop).

The underground closed loop is connected directly to water-to-air heat pumps located in various parts of the complex that provide heating or cooling depending on the user settings. A non-CFC (pollution free) refrigerant flows through this circuit. The refrigerant, coupled to an additional gas-fired boiler, maintains the temperature in vulnerable parts of the system at above 0°C, to avoid frost damage and enable better performance.

The heat pumps also have a reversing system that allows the internal building loop to act as a heat source or heat sink, depending on the zone requirements. A heat pump may cool its own zone and reject heat to the loop, while another heat pump recovers heat from the loop to heat its respective zone. The system therefore provides better comfort for its users.

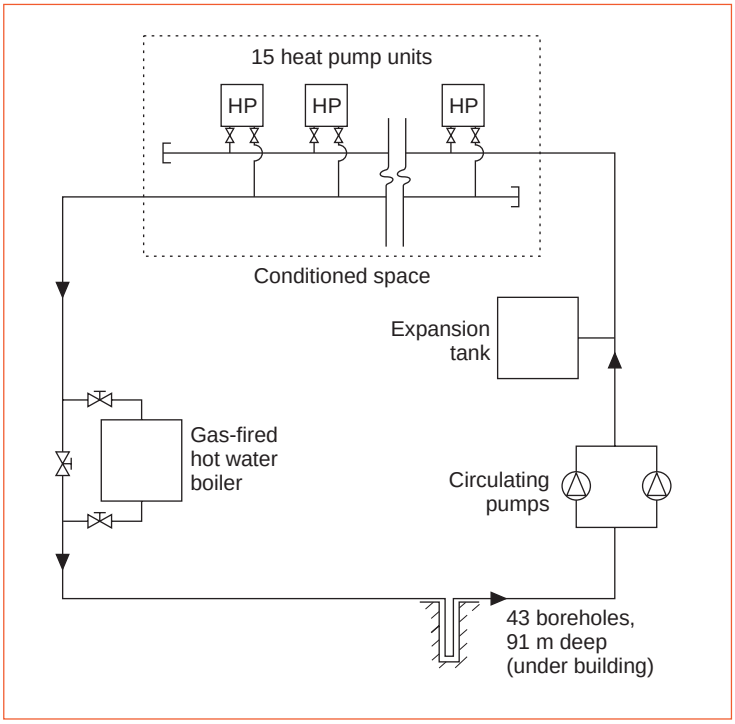

Figure 1: Diagram of the ground-source heat pump system.

The Situation

The Trustcan Realty Office is housed in a 2,600 m^2 three-storey building. The high-density location in downtown Toronto (Ontario) made it difficult to install a new large-scale system such as a heating, ventilation and air-conditioning (HVAC) system. Encouraged by Ontario Hydro to choose an energy-efficient system, the owners decided on a closed-loop design incorporating 43 boreholes (91 m depth). The boreholes are spaced a minimum 3 m apart, and are at least 4.6 m from the building foundations. The borefield runouts are located 2.1 m below the floor slab of the parking garage. These runouts are connected to reverse headers to ensure an even flow to all boreholes.

The design of the underground closed-loop system does not incorporate a heat exchanger to separate it from the internal loop, i.e. the underground loop is connected directly to the 17 water-to-air heat pumps serving the complex. These pumps vary in power from 12.3 kW to 17.6 kW, giving a total capacity of 211 kW, and are positioned on the first two floors above the suspended ceiling. Rooftop heat pumps are used on the third floor.

Because the underground loop is close to the ground surface, there was some concern that if the loop temperature dropped below freezing the building foundations might be damaged by frost. Adding the propylene ethynol solution (circulated through this part of the system by a 7.5 kW pump) and a gas-fired boiler ensures that the loop temperature remains above 0°C.

Fresh air is heated via a gas-fired rooftop unit before being ducted directly to the various heat pumps at a rate of 1,416 l/s. The ground-source heat pump system has reduced natural gas consumption by almost 96%, using only 1,574 m^3 compared to 41,910 m^3 for a conventional system. Electricity consumption is slightly higher, 552 MWh compared to 528 MWh (the two comparisons are based on a similar sized building located near the Trustcan office). Due to this massive reduction in natural gas consumption, CO_2 emissions have dropped to almost 90 tons per year.

The Company

The Oxford Properties Group is one of Canada's largest property owners and managers, with assets in excess of CAD three billion. The group owns property in the office, retail and industrial sectors in major Canadian cities.

Oxford currently owns a net 2.04 million m^2 interest in a 4.09 million m^2 portfolio of high-quality commercial properties, and 6.13 million m^2 of commercial real estate.

Economics

The overall installation costs of this ground-source heat pump system were estimated at CAD 290,500. This is CAD 78,500 more than a conventional system incorporating a variable-air-volume (VAV) arrangement with gas heating and direct-expansion (DX) cooling. The total evaluated cost for the latter option was CAD 212,000, which includes air distribution ductwork, diffusers, registers, insulation and controls. However, the GSHP system has resulted in a total annual energy cost saving of CAD 6,600 (i.e. reduced natural gas consumption of 40,336 m^3, with a slight increase of 24 MWh) in electricity consumption. This is 11.5% less expensive than a conventional system and yields a simple payback period of 12 years. However, thanks to a CAD 35,000 subsidy from Ontario Hydro, the payback period is reduced to 6.5 years.

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* IEA: International Energy Agency
OECD: Organisation for Economic Co-operation and Development

IEA

The IEA was established in 1974 within the framework of the OECD to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the 24 IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology, and research and development (R&D).

This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 40 Implementing Agreements, containing a total of over 70 separate collaboration projects.

The Scheme

CADDET functions as the IEA Centre for Analysis and Dissemination of Demonstrated Energy Technologies. Currently, the Energy Efficiency programme is active in 11 member countries and the European Commission.

This project can now be repeated in CADDET Energy Efficiency member countries. Parties interested in adopting this process can contact their National Team or CADDET Energy Efficiency.

Demonstrations are a vital link between R&D or pilot studies and the end-use market. Projects are published as a CADDET Energy Efficiency 'Demo' or 'Result' respectively, for ongoing and finalised projects.

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